D. Sc.

GROWTH RINGS IN INDIAN TREES

PART II

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I N D I A N   F O R E S T

R E C O R D S

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U T I L I Z A T I O N

VOl.   No:

THE FORMATION OF GROWTH RINGS IN INDIAN TREES.

PART II.

(a) CHAMP (Michelia champaca)   (b) KOKKO (Albizzia lebbek)

(c) SISSOO (Dalbergia sissoo)   (c) TOON (Cedrela toona).

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C O N T E N T S.

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1. Introduction.

In the part I of this series (1), a study of growth rings in seven Indian trees was made. There it was reported that in chir (Pinus longifolia), teak (Tectona grandis), laurel(Terminalia tomentosa), cutch (Acacia catechu) and semul (Bombax malabaricum), it is possible to make an accurate determination of their age, provided proper care is taken of some false rings that occasionally develop in them. It was also pointed out that the irregular marks found in the woods of jaman (Eugenia jambolana) and sal (Shorea robusta) did not have any relation with the annual growth activity and could not, therefore, be taken to indicate their age. The data collected, in course of this investigation, lead to some interesting deductions, such as, that deciduous trees did not always have growth rings nor were all evergreens without them. Moreover, the tree species studied did not seem to have any resting period in the middle of the active growth season. It was realised at that time that these conclusions were, to some extent, open to criticism, because of the small number of species on which they were based. Investigation of many more species, therefore, seemed necessary to draw conclusions, which could be generally applied to the trees in India. The present paper is the result of further work that was done in this direction. Four more species from the same locality were studied. They were toon (Cedrela toona), kokko (Albizzia lebbek), sissoo (Dalbergia sissoo) and champ (Michelia champaca). Toon was selected because it being a ring-porous wood would allow verification of the results that have already been obtained in teak(Tectona grandis). The remaining species were all diffuse-porous woods. Their selection has been made with double objects in view. Firstly, to find out whether or not the concentric lines of parenchyma cells present in their timber, form the boundaries of growth ring, and secondly, the exact position that these parenchyma cells hold in a growth ring i.e., terminal or initial.

2. Material and methods.

As in part I, the first step taken was to study the wood specimens of these four species in the Dehra Dun collection, with a view to recording the range of anatomical variation that they

they exhibited. Having thus obtained an idea of the different structures which give the impression of growth rings, an attempt was made to determine the time of occurrence of these structures in the living trees, and finally, the extent to which they could be taken for the marks of true growth rings. Altogether 60 specimens were available in the Dehra Dun collection for this examination. For the sake of field study two trees of toon (*Cedrela toona*), three of kokko (*Albizzia lebbek*), two of sissoo (*Dalbergia sissoo*) and one of champ (*Michelia champaca*) were selected. All these trees were situated in the Forest Research Institute Estate, Dehra Dun. The local and climatic conditions of these trees were more or less similar to those included in Part I (1), and have not, therefore, been repeated here. The data for this paper were collected for one full year.

The method of study was exactly the same as that of the first paper. Small blocks containing phloem, cambium and wood were taken out fortnightly or monthly. The actual condition of the cambial zone was considered to be the best criterion for determining the growth activity and dormancy. Necessary care was also taken to find out the exact position of the concentric bands of parenchyma which gave the impression of growth rings.

3. Results.

(a) CHAMP (*Michelia champaca*, Linn.)

Champ is a diffuse-porous wood and it does not show any distinct zone of early and late wood. The concentric parenchyma bands present in it, give the impression of growth marks. All of these bands, however, are not complete round the trees; some run for a few inches and then end blindly. In view of this peculiar distribution, their position in the growth ring is uncertain (Pl. I, Fig: 1). The vessels are more or less uniformly distributed but an occasional tendency to crowd towards the middle of the growth ring is not uncommon. Parenchyma cells are paratracheal, diffuse and in concentric bands. Of these, the first two types are rather scanty and have irregular shape. The cells of the concentric bands are moderately thick-walled and radially flattened. As a rule, As a rule, they are found in rows of 2-10.

In January, the tree was in full crown, and a few leaves were found in yellow colour instead of normal green. Examination of the micro-blocks taken at this time showed that the cells of the cambial zone were individually distinct. The last tissues formed in the previous growth season were thick-walled parenchyma cells, which could be easily recognised on account of their starch contents (Pl.I,Fig. 2). It would, therefore, appear that the position of concentric bands of parenchyma was terminal. However, no outward change was noticed in February and March. Microscopic examination of the blocks taken during these two months revealed that the concentric parenchyma might occur in double bands separated by a narrow belt of fibrous tissue (Pl. I, Fig.3). By April, about 50 per cent of the leaves turned yellow but they had not started falling. In May, the tree was in flower and the leaves started dropping. At this time, the cambial cells were still individually distinct, although they were somewhat swollen. During the early part of June, the tree showed growth activity in some places of the cambial zone but not all over. In July, fruits were noticed on the tree, and the diameter growth continued at a slow rate all over the cambial zone. The maximum period of growth in this species appeared to be confined to the months of August and September. During October, growth slowed down considerably, and the fruits were ripe. In November, the cells of cambial zone became individually distinct, indicating cessation of growth. The last tissues of the current year were parenchyma cells but they were not fully mature at this time. During December, the terminal parenchyma cells attained maturity and showed their starch contents (Pl. I, Figs. 4,5). Here it may be mentioned again that two bands of concentric parenchyma, intercepted by a few rows of fibres, were occasionally formed during the later part of the growth season. The earlier band was usually discontinuous, while the last band of the season was found to be complete round the tree.

(b) KOKKO (<u>Albizzia lebbek,</u> Benth.)

In the diffuse-porous wood of kokko there is no distinct growth marks. Only some faint concentric lines are present (Pl. II, Fig. 1), and these under a high power microscope appear to be due to an abrupt change in thickness of the fibre wall. At the junction, a few scattered parenchyma cells may also be found. It is not possible to say whether or not these faint marks indicate the boundary of the growth rings. Here it may be mentioned that in sapwood, which is white, the concentric marks are distinct but not so in the heartwood, on account of its darkish colour. But with the help of a microscope this difficulty in the heartwood can be always overcome. The vessels in kokko are uniformly distributed, surrounded by parenchyma cells, which often form 'eyelets' (Pl. I, Fig. 1). The other type of vertical parenchyma cells present is diffuse and usually contains crystals or gummy deposits.

In January, the trees were shedding leaves. Examination of blocks showed the cambial zone narrow and its cells individually distinct. Growth was evidently dormant at that time. As far as the woody tissue next to the cambium was concerned, it consisted mainly of fibres with a few parenchyma cells scattered in them. During February, the leaves continued dropping and by March two of the trees under observation were entirely leafless, while the other still had a few yellow leaves sticking on to it. In the first week of April, new foliage was coming out, but no change in the cambial zone was noticed. By the end of April, the trees had crown almost half full, and cambial cells at that time were distinctly swollen, although there was no difficulty in distinguishing them individually. During May, the crown attained more or less full size, and the cells in the cambial zone became disorganised. In the first week of June, diameter growth was noticed in the main bole. The renewal of activity was at first in patches and by the end of the month, the cambium cells all round the tree began to produce new cells. At this time, it was possible to examine carefully what brings about the growth marks. Growth in the previous year was terminated by thick-walled fibres, which for the most part were radially flattened, while the early fibres in the current year's wood were widest radially. Moreover, the fibres in late wood were comparatively thicker walled than those of the early wood. All these differences were sufficiently

sufficiently prominent to bring about the demarcation of growth rings (Pl. II, Fig. 5). Here again a few scattered parenchyma cells were found embedded in the late wood but these could not be called terminal because of their similar distribution throughout the wood (2,3). The rate of diameter growth was fast during July, August and September but it slowed down considerably in October and stopped altogether in early November. Due to immature state of cells at this time, it was not possible to find out exactly what types of cells terminated the season's growth. But in December, when the late wood of the current year was fairly mature, growth seemed to have terminated mainly by fibres which had comparatively thick walls (Pl. II, Fig. 4).

In course of this investigation, it has been found that occasionally some patches of fibres may form a thick band, without having any diffuse parenchyma. This structure often gives the impression of growth marks but it does not seem to have any relation either with the commencement or with the cessation of growth. There is another structure which also needs mentioning in this connection. The paratracheal parenchyma cells form a complete band all round the stem and show up somewhat like the mark of a growth ring. This is not a common occurrence but one twig has shown it, without having any relation with the commencement or cessation of growth.

(c) SISSOO (Dalbergia sissoo, Roxb.)

Sissoo is a diffuse-porous wood without having any distinct zone of early and late wood (Pl. III, Fig. 1). The light coloured sapwood shows fairly distinct growth rings but not the heartwood, which is usually of darkish colour. The alternate bands of dark and light coloured tissue present in the heartwood often give the impression of growth marks but they do not have any relation whatsoever with the true growth rings. Distribution of vessels is more or less even throughout the wood. The parenchyma cells are paratacheal confluent, metatracheal diffuse and in thin concentric lines. In size and shape the first two types are similar. But the last type is different and it occurs at more

more or less regular intervals. Taking the concentric lines as the boundaries of growth rings, sissoo shows 3-10 rings per inch.

In January, the trees were almost leafless. Micro-blocks taken out at this time showed the growth activity to be dormant. The woody cells next to the cambium were fibres, but where the vessels were occupying adjacent positions next to the cambium, a few confluent parenchyma cells might also be noticed. During February, new leaves were coming out along with the flowers but internally no change was noticed. The crown attained full size during March and April. In the second half of April, the cells of the cambial zone were swollen but growth activity was not noticed. By the beginning of May, diameter growth was recorded in the trunk. The newly formed tissue became mature some time in June. At this time it was possible to notice the first tissue of the season and this was a thin, continuous band of parenchyma cells. Furthermore, the difference in the size of the vessels was helpful in locating the boundary of the growth ring. It was not uncommon to find comparatively small-sized vessels in the extreme late wood and large vessels in the early wood, thus bringing about a contrastive structure (Pl. III, Figs. 2,3). There was also considerable difference in the thickness of the fibre wall of the late wood of the previous year and that of the early wood of the current year. In a varying degree, all these different structures were responsible for bringing about the boundary of the growth ring. Now, coming to the rate of growth, it was fairly fast in June and became faster in July and August (Pl. III, Figs. 2,3). In September it slowed down and stopped altogether by the middle of October. At this time, the fruits were turning brown but remained on the trees. In November no internal or external change was noticed. During December, the extreme late wood of the current year became fully lignified. The woody tissues placed next to the cambial zone, were mainly fibres, with a few parenchyma cells adjacent to or confluent with the late vessels (Pl. III, Fig. 4). The old leaves started turning yellow about this time and began to fall.

(d) TOON (*Cedrela toona*, Roxb.)

The wood of toon is ring-porous to semi-ring-porous, in which the zone of early wood is not, as a rule, very well defined (Pl. IV, Fig. 1). The large vessels surrounded by narrow layers of parenchyma cells, occur in radial rows of 2-6. Very rarely these vessels form the concentric bands known as 'pore-zone'. The transition from early to late wood is usually gradual, the vessels becoming smaller in diameter and the fibre walls thicker. The growth rings are fairly distinct and they vary from 2-15 per inch. There are, however, some concentric bands of gum ducts which give the impression of growth rings but they are not always continuous nor is it difficult to distinguish them from the marks of true growth rings. In some specimens, some fine lines of concentric parenchyma cells were noticed. These lines looked like the initial type, but the vessels in their neighbourhood did not exhibit such variation in their size as those near about the true growth marks. By mere examination of wood samples, it is difficult to say whether or not these fine lines have any relation with the commencement or cessation of growth (Pl. IV, Fig. 1).

In January, the trees were entirely leafless. Examination of micro-blocks showed that the growth was dormant. Wood cells next to the cambial zone were fibres and they were fully lignified. By the middle of February, new leaves were noticed coming out. At this time the cambial zone was swollen although no growth activity could be detected. Renewal of cambial activity was started some time in the first week of March (Pl. IV, Fig. 2), when the leaves had not attained full size. By the third week of March, 2-3 rows of early vessels were formed and they were placed adjacent to the initial parenchyma band, which was very distinct at this time. During April, the trees were in flowers, and the growth was progressing at a moderate speed. In May, the rate of growth was more or less the same but it became fast during June, July and August. In the month of September, growth slowed down considerably and stopped altogether sometime in the first week of October. During November, there

there was no change, either externally or internally. In December, the leaves started dropping, and the fibres which formed the last tissues of the year were fully lignified. It is of interest to note here that in tree No.1 formation of a false ring was noticed. The structure reponsible for it was, a thin band of concentric parenchyma produced in the middle of the active growth season. All the micro-blocks, however, did not show this structure but only two - one that was taken out on the 27th July and the other, on the 6th November (Pl.IV, Figs. 3, 4). The reason for its absence in the blocks taken out between these two dates and after, could not be understood. It is quite possible that this band was not formed all round the stem. Being an incomplete band, it was present in some blocks and absent in others. In any case, these parenchyma bands do not seem to have any relation with the commencement and cessation of growth and should not, therefore, be taken as the demarcation of ~~the~~ true growth ring.

4. Discussion.

(a) Anatomical variation in the formation of growth rings.

Amongst the species included in this paper, toon (Cedrela toona) is the only ring-porous wood; the rest are all diffuse-porous. From the earlier chapter, it will be seen that toon has fairly distinct growth rings. The large and scattered vessels of the early wood, associated with initial parenchyma cells and thin-walled fibres, show up distinctly against the thick-walled late wood. There is, therefore, no difficulty in locating the demarcation of growth rings. In this connection, caution should be taken of the fine bands of concentric parenchyma cells, which are occasionally formed in the middle of the active season and give the impression of growth marks. This investigation has shown that these concentric bands have no relation whatsoever either with the commencement or with the cessation of growth. The method of distinguishing the false from the true growth marks is not also very difficult. Both types are associated with concentric parenchyma bands but in the case of of false marks, the vessles on their either side are more or less of the same size, while the size of the vessels on different sides of the true marks shows a great difference. In this connection, it will be remembered that the false ring in the ring-porous wood of teak (Tectona grandis) was found to be due to thick-walled fibres produced in the middle of the active growth season (1). The reason for which toon produces concentric parenchyma cells and teak produces thick-walled fibres, is not at all clear. Furthermore, it is evident that all the ring-porous woods do not react to the abnormal conditions of growth in the same way. Each behaves differently and produces different structure.

It has been stated before that investigation in 1937 was carried out on two toon trees. The tree No.1 showed occurrence of a false ring but not the tree No.2. Moreover, the false ring in tree No.1 could not be traced all round the tree; only two micro-blocks had shown it. In December 1938, one large block of wood from each of these trees was taken with a view to finding out any correlation that might exist between the prevalent climatic conditions and the false growth rings. The block taken from tree No.1 had 4 growth rings i.e., rings for 1935, 1936, 1937 and 1938. Amongst these, false ring was noticed in the wood formed in 1935, 1937 and 1938, but not in 1936. An analysis of the prevalent temperature and rainfall for these four years was then made. The concentric parenchyma band, which is responsible for the false marks, is formed some time in the month of May. The temperature and rainfall during April, May and June show that in 1936 there was a high rainfall in May (Table I). Besides this, other differences were not of much significance. It would, therefore, appear ~~quite possible~~ that in May 1935, 1937 and 1938, scarcity of water brought about some physiological crisis which induced the formation of concentric parenchyma cells during the middle of the active growth season. But in the case of tree No.2, there was no false ring in any of these years. Why the tree No.1 repeatedly showed the false rings and the tree No.2 did not, is difficult to understand. Is it possible that the tree No.1 is more

more susceptible to drought than the tree No.2? However, this is a problem beyond the scope of the present paper and may well be left to the plant physiologist to solve.

Table I. Temperature and rainfall at Dehra Dun (1935-38).

	Mean temperature in degrees F.				Rainfall in inches.			
	1935	1936	1937	1938	1935	1936	1937	1938
April	70.15	75.85	73.55	78.20	0.93	0.34	2.28	0.09
May	84.45	85.15	82.70	85.70	0.40	5.42	0.28	0.90
June	87.60	79.65	83.35	81.85	3.27	15.34	15.52	14.77

Now the diffuse-porous species may be considered here. Amongst these, champ (Michelia champaca) alone shows prominent growth marks. These growth marks are composed of concentric parenchyma bands which show up prominently against the general structure of the wood. On microscopic examination of the blocks collected during the year 1937, it has been found that these bands terminate the year's growth. Moreover, a block taken out in December 1938 has been studied and the result obtained in 1937 has been confirmed. There can, therefore, be no doubt that these concentric bands are terminal. In this connection, it may be pointed out here that one may occasionally come across two concentric bands of parenchyma separated by a very narrow layer of fibres. By careful examination it has been found that both these bands do not run completely round the tree. The inner band usually runs for a short distance and ends abruptly, But the outer band which usually runs completely round the tree, is the true terminal band. For the determination of the age of a champ tree it will, therefore, be advisable to ignore the inner band and count only the outer band as true growth mark.

From the above it will be seen that the concentric parenchyma bands are single in some years and double in others. The reason for this is not clearly understood. Moreover, an attempt to correlate the monthly mean temperature and rainfall to the occurrence of these double bands has proved abortive.

That the growth rings in cutch (*Acacia catechu*) are also due to the terminal parenchyma bands, has already been reported (1). But these bands are not so prominent as those found in champ. The terminal parenchyma cells in cutch are usually in a single row and require careful microscopic examination to detect. On the other hand, in champ, they are in rows of 2-10 cells, and show up distinctly even on the longitudinal surfaces. Thus, it will be seen that the degree of visibility of terminal parenchyma bands in different species is not the same.

In kokko (*Albizzia lebbek*) and sissoo (*Dalbergia sissoo*) the growth rings are not, as a rule, very prominent. A hand lens is always necessary for their determination and in special cases, help of a microscope may also be required. In kokko, the visibility of growth marks is due to the difference in the thickness of the fibre wall of the early wood in contrast with that of the late wood of the previous year. Other structures, which have been found to give the impression of growth marks, without having any relation with the commencement and cessation of growth activities are, bands of fibre devoid of any parenchyma cells, and paratracheal parenchyma, forming a thick continuous band. Both these types will have to be ignored when a determination of the age of a tree is to be made. Lastly, in sissoo, it is the initial parenchyma band which delimits the season's growth. These bands are often wavy and are likely to be confused with the confluent parenchyma cells found all over the wood. But the confluent type is usually ~~thicker~~ wider and more wavy than the initial bands. Moreover, the confluent parenchyma cells are seldom continuous all round a tree, while the initial types are. Again, the size of the vessels in the early and in the late wood is often helpful in locating the initial parenchyma cells. The difference in thickness of the fibre wall also shows enough contrast to locate the growth ring. It will, therefore, be seen that although the growth rings in sissoo are somewhat difficult to determine yet by careful examination one can always find them.

(b) <u>Relation between foliar periodicity and formation of growth rings.</u>

Wright (4) was not able to find any relation between deciduous habits of trees and the formation of growth rings in their wood. The author (1) also in a previous publication, drew a similar conclusion. In the present paper four species have been included. Of these, three are deciduous namely, kokko (<u>Albizzia lebbek</u>), sissoo (<u>Dalbergia sissoo</u>) and toon (<u>Cedrela toona</u>), and one is evergreen i.e., champ (<u>Michelia champaca</u>). All of them without exception have shown growth rings. It will, therefore, be seen that evergreen habit of a tree does not always mean absence of growth rings nor all deciduous trees have them. These two phenomena do not necessarily go together, as it is believed in certain quarters.

(c) <u>Relation between cambial activity and foliar development.</u>

The data collected on this point by different workers in Europe and North America, have been fully discussed in Part I of this investigation. It has been ~~there~~ pointed out, how some of the Indian species differ from the European species. Based on Indian trees, the author has drawn the conclusion that the cambial activities start some time after the development of new foliage and that there is no difference in this respect between the ring-porous and the diffuse-porous species. For the deciduous trees included in this part, the same remarks will hold good; because out of three trees, including both ring-porous and diffuse-porous species, not a single one has shown cambial awakening until the crowns were at least half full (Table II). Even in the case of evergreen champ (<u>Michelia champaca</u>), the cambial activity did not start till the greater portion of the crown was covered with new leaves. It will, therefore, be seen that the data collected for the present paper fully confirm the conclusion that was arrived at in the previous paper.

Table II. Foliar development, and commencement and cessation of diameter growth.

Species.	Foliar development.	Commencement of growth.	Cessation of growth.
Champ (*Michelia champaca*)	An evergreen tree.	1st week of June.	1st week of November.
Kokko (*Albizzia lebbek*)	1st week of April.	1st week of June.	1st week of November.
Sissoo (*Dalbergia sissoo*)	3rd week of February.	1st week of May.	2nd week of October.
Toon (*Cedrela toona*)	2nd week of February.	1st week of March.	1st week of October.

(d) Variation in the commencement of diameter growth in different species and individuals of same species.

The first species of the season to show diameter growth was toon (*Cedrela toona*) and it happened in early March. Next came sissoo (*Dalbergia sissoo*), for its cambial activities in the main bole were noticed in May. Within the first week of June, kokko (*Albizzia lebbek*) and champ (*Michelia champaca*) showed renewal of diameter growth (Table II). Thus, it will be seen that the ring-porous species was the first to start growth activity and the evergreen species was the last. In this connection, the results obtained in part I are of interest. There, it was reported that "there was no difference in the commencement of growth activity in ring-porous and diffuse-porous species, nor in the deciduous and evergreen dicotyledons." Teak (*Tectona grandis*), (1) started growing in diameter sometime in June and July, while in the present case, toon (*Cedrela toona*) showed the growth activity in March. It would, therefore, appear that all the ring-porous species do not start growing at the same time. They vary in this respect as much as the diffuse-porous species do. Here it may be pointed out that

that commencement of diameter growth in the evergreens. ~~that they~~ seems to start comparatively late in the season. For jaman (Eugenia jambolana) (1) began to grow in August, while champ in the middle of June. This, however, is nothing but an indication of late growth in the evergreens, and will require further confirmation before it can be generally applied to all of them.

In part I, one to three weeks difference in growth activity was reported in the individuals of same species. Data collected for the trees included in this paper, did not bring out any new fact. Moreover, it was not possible to correlate these differences to any environmental conditions.

(e) Progress of growth throughout the season.

Some American workers (1), have reported an occurrence of resting period in the middle of active growth season. This phenomenon was not noticed in any of the species studied. Growth once started, was continued till it ceased for the season. The rate of growth in different species, however, was not the same throughout the active period. Toon (Cedrela toona) for example, showed fast growth to start with. In fact, within two weeks of the cambial awakening the early vessels and its surrounding cells were completely formed. Then, it slowed down but became fast again during June, July and August. In September the growth was very sluggish and it stopped altogether in October. Thus it will be seen that like chir (Pinus longifolia) and teak (Tectona grandis) of part I, toon has got two distinct periods of growth. In each period, growth is fast to start with, and is followed by a slow growth.

Table III. Period of maximum growth in different species.

Species.	Period of maximum growth.
Champ (Michelia champaca)	August and September.
Kokko (Albizzia lebbek)	July, August and September.
Sissoo (Dalbergia sissoo)	July and August.
Toon (Cedrela toona)	June, July and August.

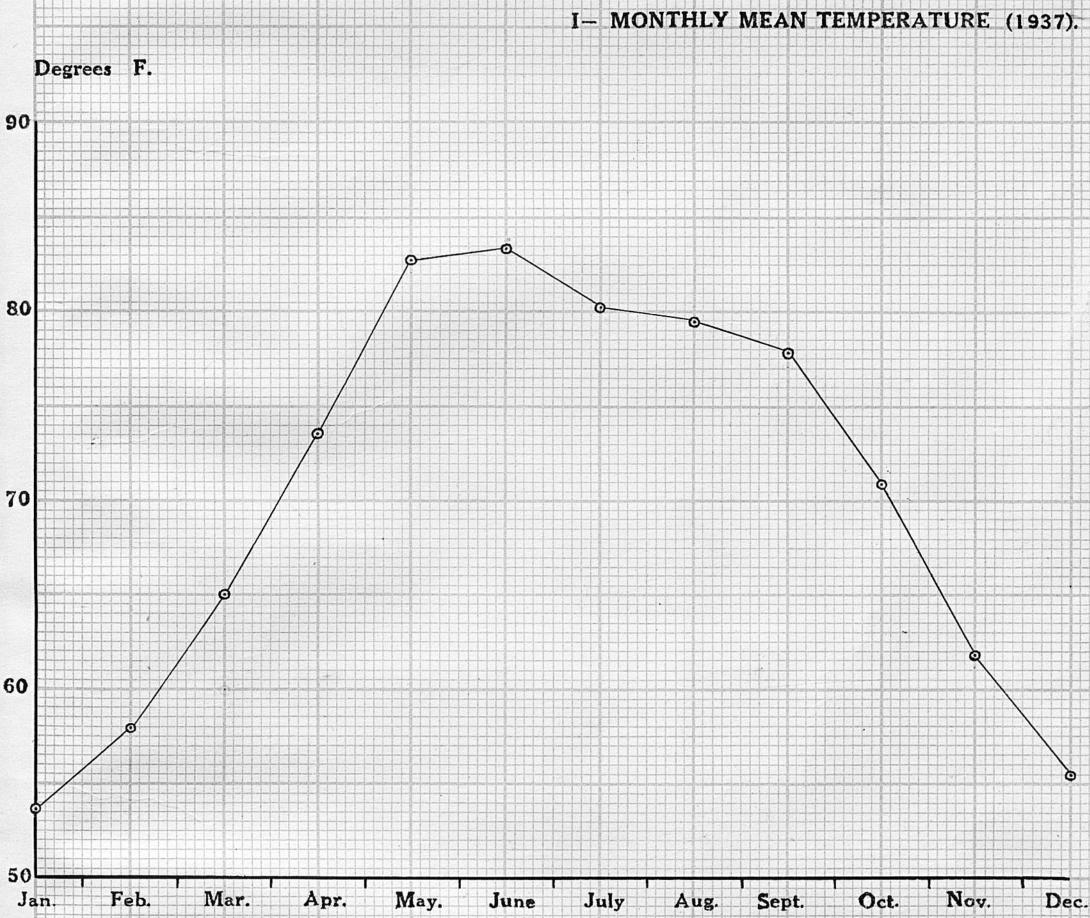
The diffuse-porous species, irrespective of deciduous and evergreen habit, showed slow growth in the beginning; they, however, had fast growth during the monsoon. After that, growth gradually slowed down till it stopped altogether for the season. The maximum periods of growth were sometime from July to September (Table III). It will, therefore, be seen that the progress of growth in these species was similar to what has already been recorded in cutch (Acacia catechu), laurel (Terminalia tomentosa) and semul (Bombax malabaricum) (1).

Now, as regards the cessation of growth, there was not much difference in various species. Toon (Cedrela toona) was again the first species to show cambial dormancy and this occurred in the first week of October (Table I). In the second week of October, sissoo (Dalbergia sissoo) became dormant and the remaining two species stopped growing during the first week of November. The cessation of growth in the species included in this paper, therefore, does not show much difference from those in the previous publication (1).

(f) Relative importance of the factors that control the growth activity.

The author (1) has already made a general survey of the factors, which are known to control the growth activities of forest trees. For the sake of convenience, these factors are grouped under two heads, external and internal. Under the external factors, temperature, humidity and rainfall are considered and under the internal factors, heredity and growth-promoting substances are discussed.

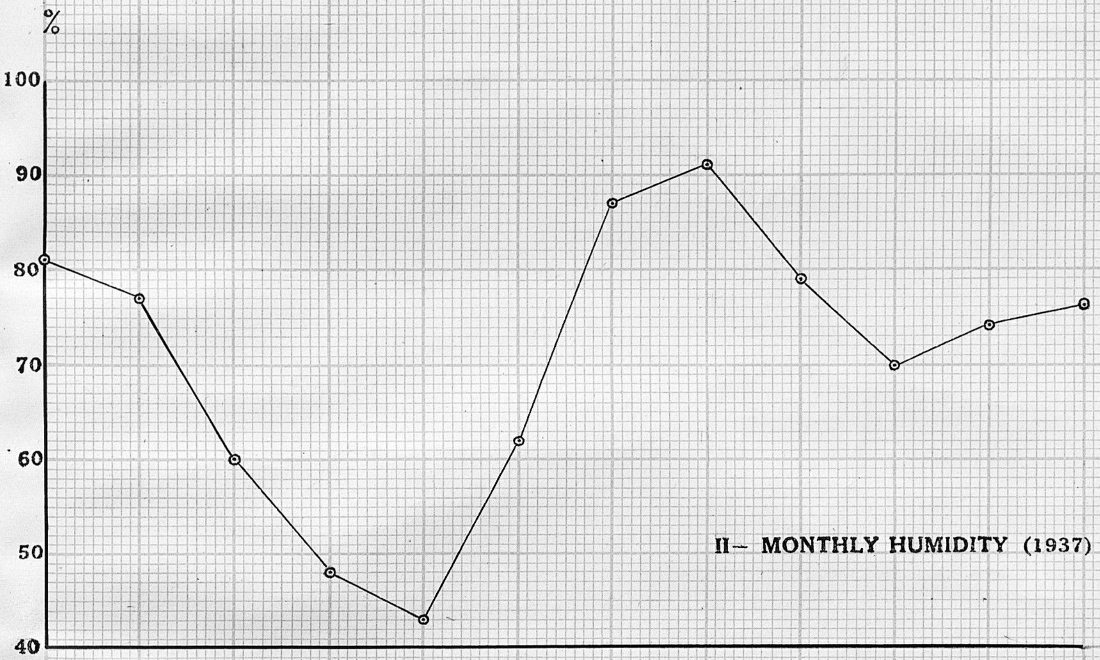
Considering the data collected during the present investigation, it will be seen that toon (Cedrela toona) started diameter growth when the temperature was 63°F (Curve I). On the other hand sissoo (Dalbergia sissoo) started growing at about 80° F, and kokko (Albizzia lebbek) and champ (Michelia champaca) at 83° F. Amongst these, the first two species ceased to grow at 73° F. and the last two at 65° F. From this, it would appear that the temperature recorded for each species gives no indication of the minimum temperature at which it can grow. In a previous paper (1), for which data were collected for three


I– MONTHLY MEAN TEMPERATURE (1937).
Degrees F.
90
80
70
60
50
Jan.
Feb.
Mar.
Apr.
May.
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

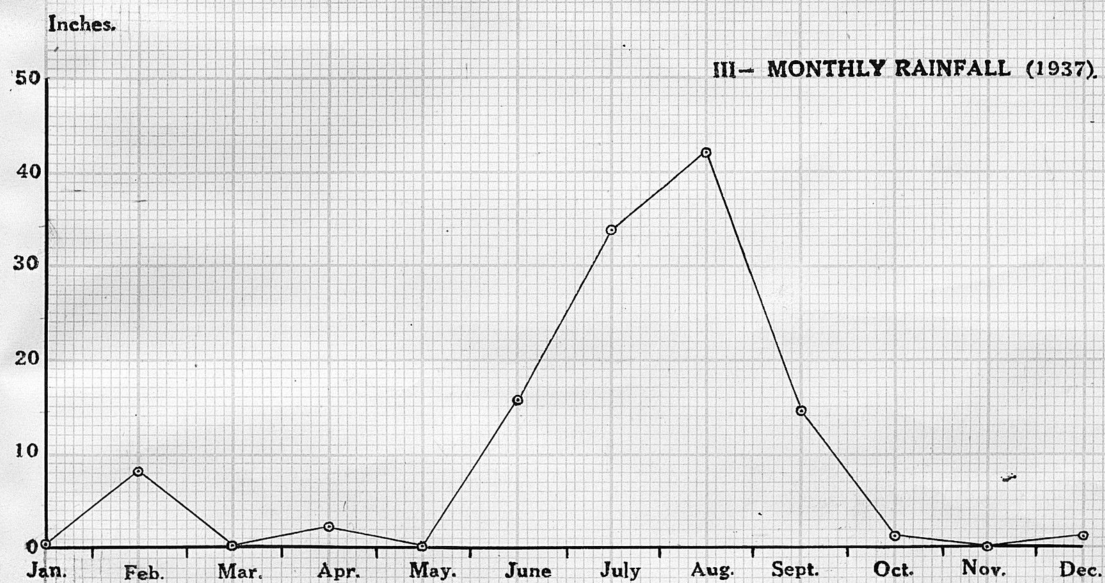
three consecutive years, temperatures at the commencement and cessation of growth did not show any direct relation with these two growth phenomena. In view of all this, it seems doubtful whether the temperature recorded has been the deciding factor in the growth activity of these trees. The data collected, however, are of some interest. For they show, for example, in toon (Cedrela toona) the diameter growth is possible even when the temperature is as low as 63° F. Similarly, some indication of the low temperature, at which the remaining species normally grow, is brought to light.

Rainfall and humidity are now the two external factors which remain to be discussed. That these two are inter-related at Dehra Dun has already been pointed out, for they are both low during April, May and June. The ring-porous wood of toon (Cedrela toona), it will be noticed, started diameter growth in March after a rainfall of 8 inches in February. During April and May, rainfall was very little and the rate of growth was rather slow. The maximum growth was during the months of June, July and August, when rainfall was very high. But the reason for slowing down in September is not very clear, for the rainfall in September was about as much as it was in June. Moreover, some correlation has already been found between the scanty rainfall during May 1935, 1937 and 1938, and the formation of false growth rings in toon wood of those years. On the other hand, the author has not been able to find out any direct relation between rainfall and growth activity in the ring-porous wood of teak (Tectona grandis) (1). In view of these contradictory observations, further investigation on ring-porous species seems to be necessary to determine the extent of control which the prevalent rainfall has on the growth activity and dormancy of these trees.

Now as regards the diffuse-porous species, they all started growth activity during the dry months of the year. On the face of it, this seems to be strange, but as has been already reported (1), it is not an uncommon occurrence in the timber species of India.



%
100
90
80
70
60
50
40
II– MONTHLY HUMIDITY (1937)



Inches.
50
40
30
20
10
0
III– MONTHLY RAINFALL (1937).
Jan.
Feb.
Mar.
Apr.
May.
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

In this connection the conclusion arrived at by Wright (4) in Ceylon is of interest. He has reported that "low humidity and scanty rainfall are clearly associated with leaf-fall." But an analysis of the data collected for three deciduous species included in this paper, does not show an agreement with Wright's conclusion. For example, leaf-fall started in sissoo (Dalbergia sissoo) and toon (Cedrela toona) in December and the new leaves came out in February. And kokko (Albizzia lebbek) showed a slight difference from this. It began dropping leaves in January and remained entirely leafless throughout March; and in April new foliage was noticed on it. By comparing the above data with curves 2, and 3, it will be seen that some relation seems to exist between the dry weather and the leafless condition of trees but the driest month of the year does not coincide with the time of leaf-fall.

It is clear from the above discussion that none of the external factors recorded by the author seems to be directly responsible for the commencement and cessation of growth in the species investigated. This is, perhaps, due to the fact that these factors are so inter-related that the effect of any particular one is difficult to be isolated. This question has been discussed in detail in a previous paper (1) and need not be repeated here.

Now, with regard to the internal factors our present knowledge is very limited. Heredity has for a long time been recognised to play the greatest part. More recently, substances, which promote as well as stop growth, have been attributed to be mainly responsible for the growth phenomenon. Although considerable work has been done on this subject, yet the complex nature of the problem is not at present clearly understood.

5. Summary.

(a) In the ring-porous wood of toon (Cedrela toona), growth rings are fairly distinct. It also has some faint growth marks which have no relation with the commencement and cessation of growth. The method of distinguishing these faint marks from the true growth marks is pointed out.

(b) Champ (Michelia champaca) has distinct growth marks. Each year's growth is terminated by a concentric band of parenchyma cells. Occasionally broken concentric band, very near the true terminal band, is also noticed. The broken band has no relation with the cessation of growth and should not be taken as a demarcation of growth ring.

(c) Growth rings are present in kokko (Albizzia lebbek) but they may not be always easy to detect. The size and shape of the cells formed in different seasons are mainly responsible for bringing them out. Some structures which give the impression of growth marks but have nothing to do with the commencement and cessation of growth are also pointed out.

(d) Growth rings may be difficult to detect in sissoo (Dalbergia sissoo), but they are always present. The initial bands of parenchyma cell usually demarcate the growth rings.

(e) There seems to be no relation between the deciduous and evergreen habit of trees and the formation of growth rings in their timbers.

(f) Amongst four species investigated, none has shown diameter growth in the trunk before half the crowns were covered with new foliage.

(g) Toon (Cedrela toona) was the first to show diameter growth and was followed by sissoo (Dalbergia sissoo), kokoo (Albizzia lebbek) and champ (Michelia champaca). Thus, the ring-porous species was the first and the evergreen the last in this respect.

(h) The difference in the commencement of growth in the trees of the same species was found to vary from one to three weeks. But this difference could not be correlated to any external factors or environmental conditions.

(i) The progress of growth in the ring-porous wood of toon (Cedrela toona) has two distinct periods; a fast growth is followed by a slow growth in each period. But in the diffuse-porous woods of champ (Michelia champaca), kokko (Albizzia lebbek) and sissoo (Dalbergia sissoo) there is only one period of fast growth, preceded and followed by periods of slow growth.

(j) No species has shown any resting period in the middle of the active growth season.

(k) All species stopped growing within four weeks. This happened from the first week of October to the first week of November.

(l) The external and the internal factors, which control growth in a tree, are discussed in brief. It is pointed out that no final conclusion can be drawn at present because of our imperfect knowledge on the subject.

6. References.

1. Chowdhury, K.A. — The formation of growth rings in Indian trees, Part I. Indian Forest Records Vol.II, No.1, 1938.

2. Do. — The so-called terminal parenchyma cells in the wood of _Terminalia tomentosa_, W.& A. Nature, 133,1934.

3. Do. — Terminal and initial parenchyma in the wood of _Terminalia tomentosa_ W.& A. New Phytologist, 35: 4, 1936.

4. Wright, H. — Foliar periodicity of endemic and indigenous trees in Ceylon. Ann. Royal Bot. Gard. Peradeniya, 2, 1904-5.

EXPLANATION OF PLATES.

(All are cross sections).

PLATE I. CHAMP (Michelia champaca).

Fig. 1. Normal wood showing growth rings in gross structure. (x 10)

Fig. 2. Tree 1, 15th March 1937, showing dormant cambium before commencement of growth. Note the parenchyma band that terminates seasonal growth. (x 20).

Fig. 3. Tree 1, 29th November 1937, showing growth of the current year. Note the double bands of parenchyma formed in 1936. Compare Fig. 4. (x 20).

Fig. 4. Tree 1, 16th December 1937, showing current year's growth. Note absence of double concentric bands in 1937. (x 20).

Fig. 5. Tree 1, 15th January 1938, showing terminal parenchyma band formed in 1937. (x 110).

PLATE II. KOKKO (Albizzia lebbek).

Fig. 1. Normal wood showing demarcation of growth rings. (x 10).

Fig. 2. Tree 1, 6th July 1937, showing growth activity up to July. Note demarcation of growth ring. (x 20).

Fig. 3. Tree 2, 6th January 1938, showing dormant cambium and a part of 1937 growth ring. (x 20).

Fig. 4. A portion of Fig. 3 at higher magnification. Note the fibres terminate the growth season. (x 200).

Fig. 5. A portion of Fig. 2 at higher magnification, showing size and shape of fibres at the boundary of growth ring. (x 200).

PLATE III. SISSOO (Dalbergia sissoo).

Fig. 1. Normal wood showing growth rings in gross structure. (x 10).

Fig. 2. Tree 1, 22nd June 1937, showing growth of the current season. Note parenchyma cells are the first tissues of the season. (x 20).

Fig. 3. Tree 1, 27th July 1937. Note growth marks gradually become more prominent; compare Fig. 2. (x 20).

Fig. 4. Tree 1, 6th November 1937, showing dormant cambium. Note the fibres terminate the seasonal growth. (x 20).

PLATE IV. TOON (<u>Cedrela</u> <u>toona</u>).

Fig. 1. Normal wood showing growth rings in gross structure. Note the distinct and the faint growth marks. (x 10).

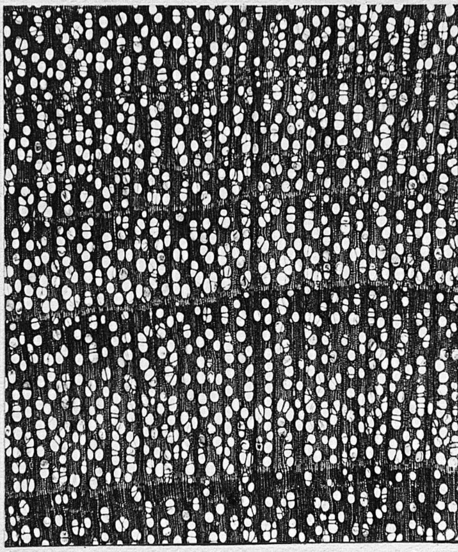
Fig. 2. Tree 2, 15th March 1937, showing active cambium and newly formed wood. (x 20).

Fig. 3. Tree 1, 27th July 1937, showing the line of concentric parenchyma formed during mid-growth season. (x 20).

Fig. 4. Tree 1, 6th November 1937, showing the same band. (x 20).

Fig. 5. Tree 1, 1st December 1938, showing growth rings for 1935, 1936, 1937 and 1938. Note the presence of false growth marks in 1935, 1937 and 1938 but not in 1936. (x 10).

K.Kerr.



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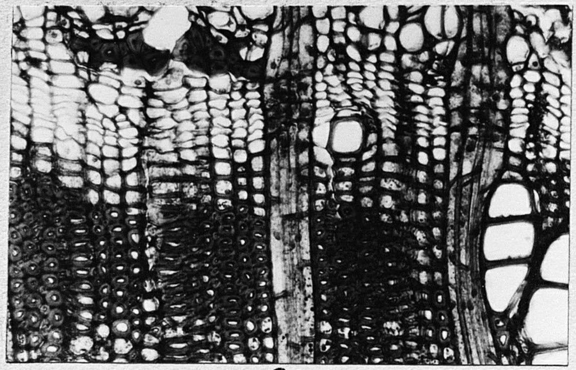

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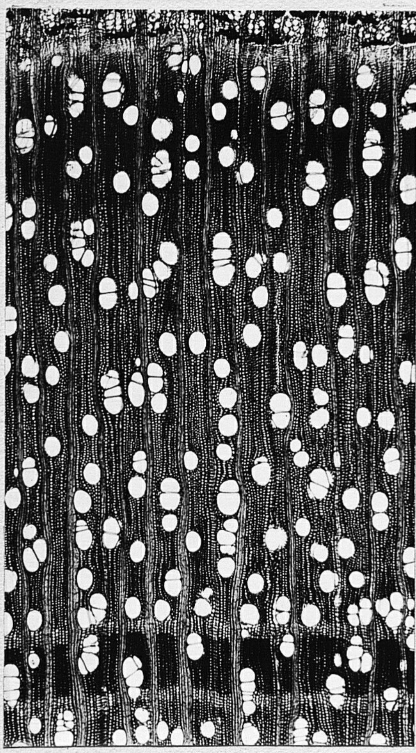

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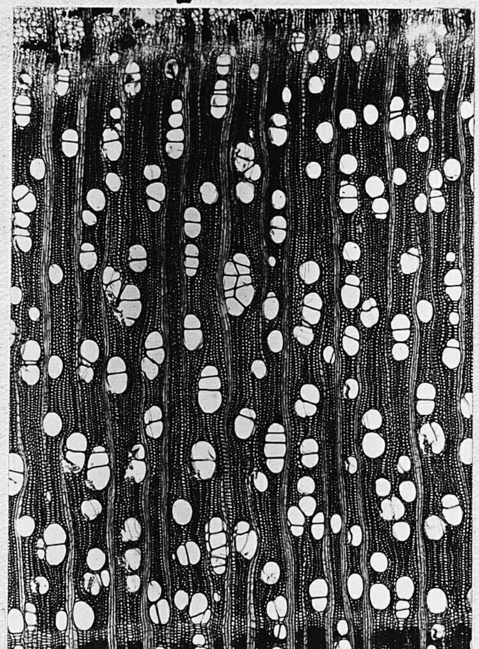

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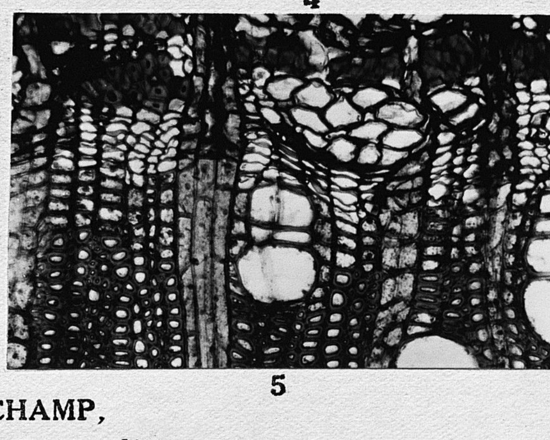

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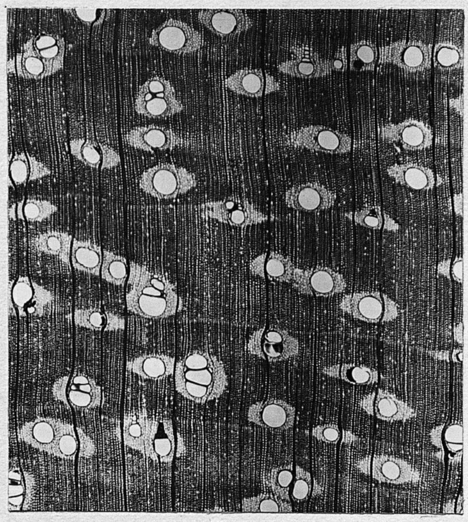
CHAMP,

Michelia champaca, Linn.



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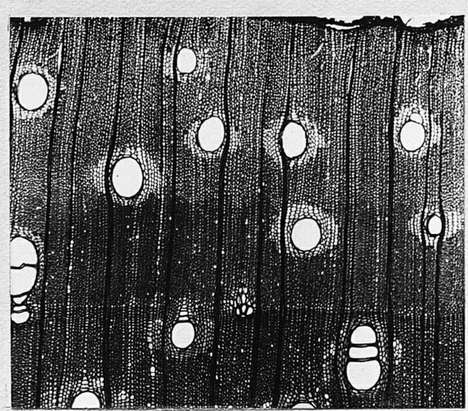

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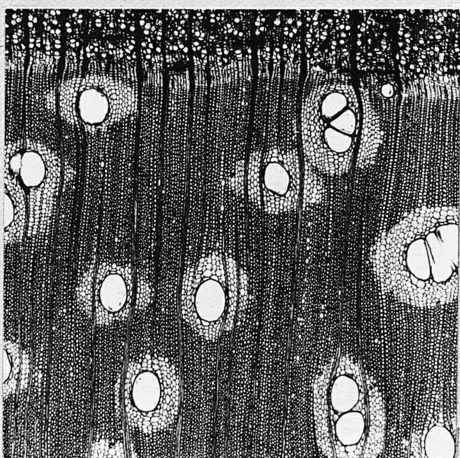

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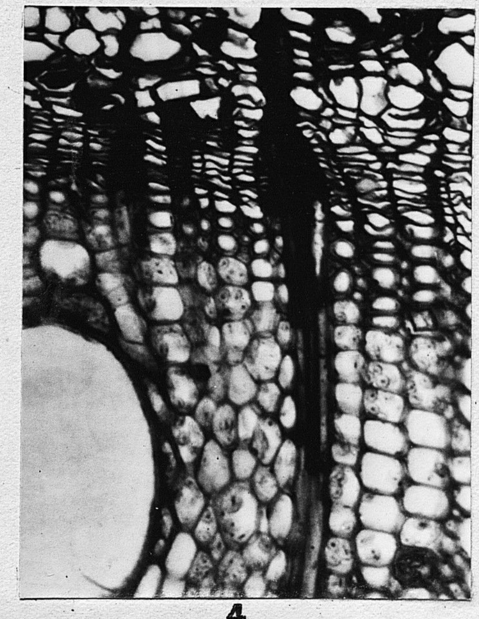

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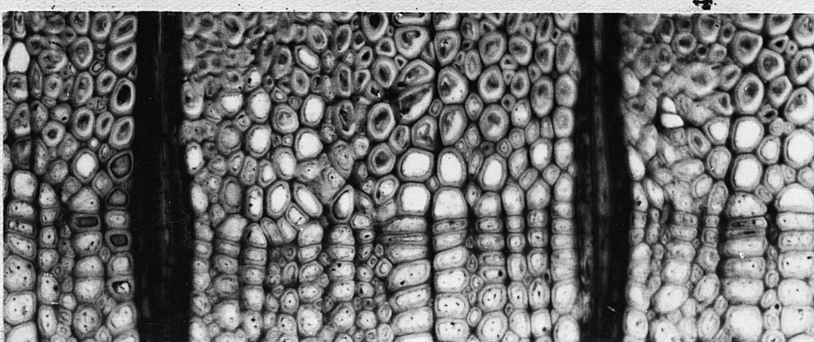

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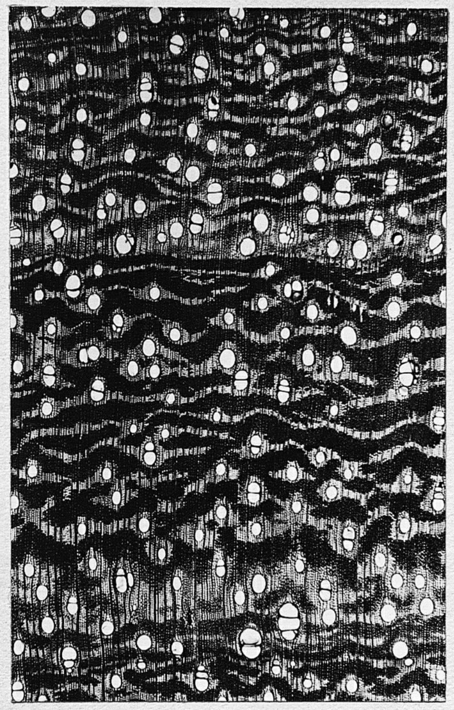
KOKKO,

Albizzia lebbek, Benth.



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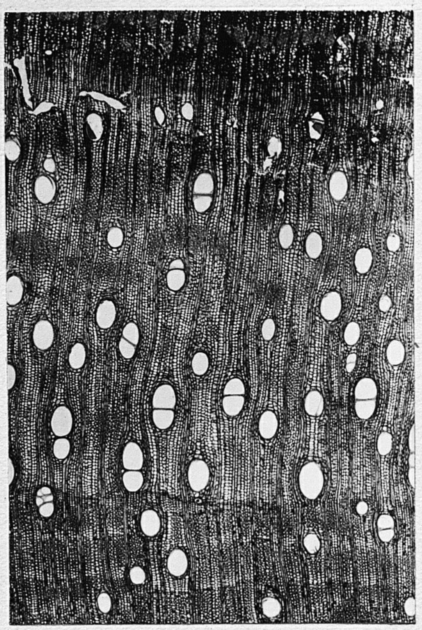

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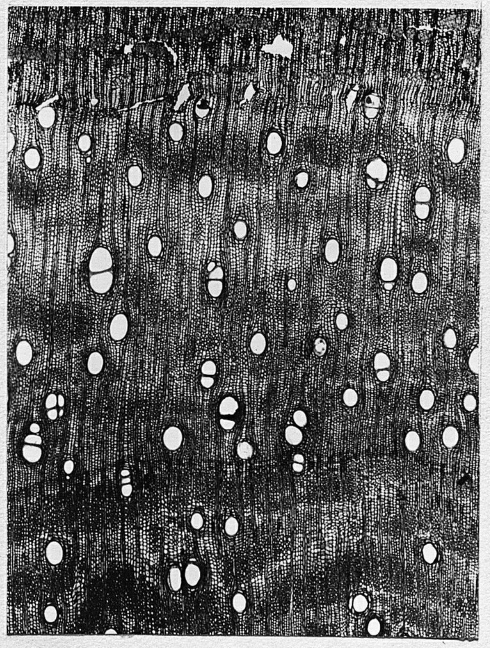

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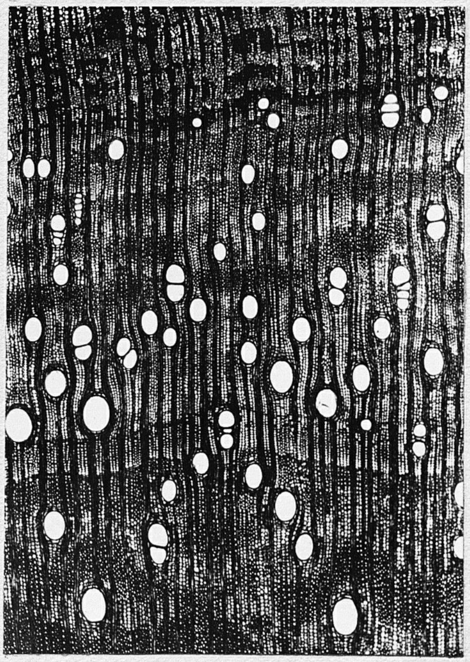

4

SISSOO,

Dalbergia sissoo, Roxb.

TOON,

Cedrela toona, Roxb.